Towards an Interannual to Decadal Local Sea Level Forecasting System

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Do we need it? The Challenge of Climate Change and Sea Level Rise Adaptation

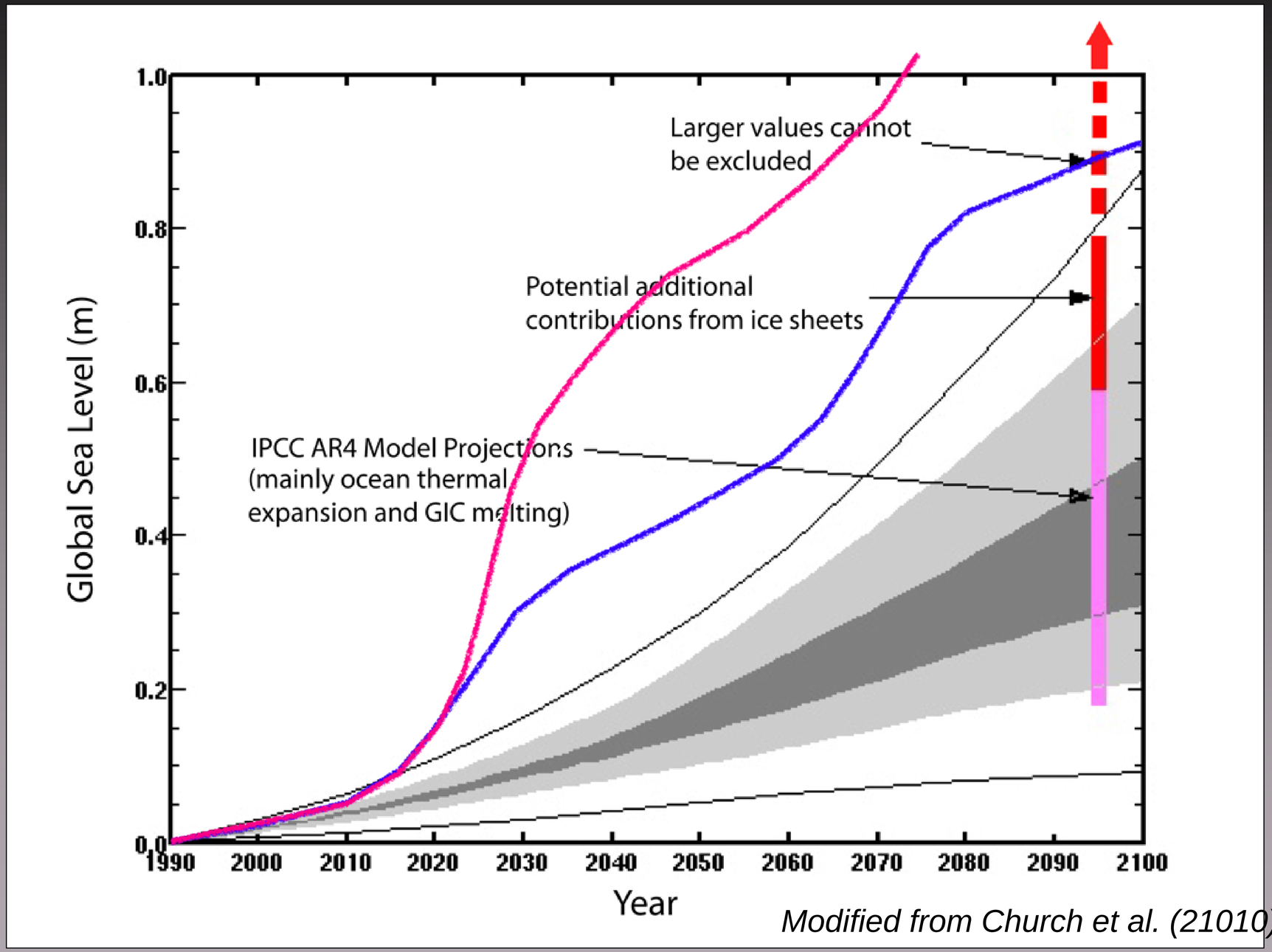
Can we do it? Cummulative Equation of Local Sea Level Changes
A Modular System Model

Current Status: Overview of available modules
Next Steps

Do we need it?

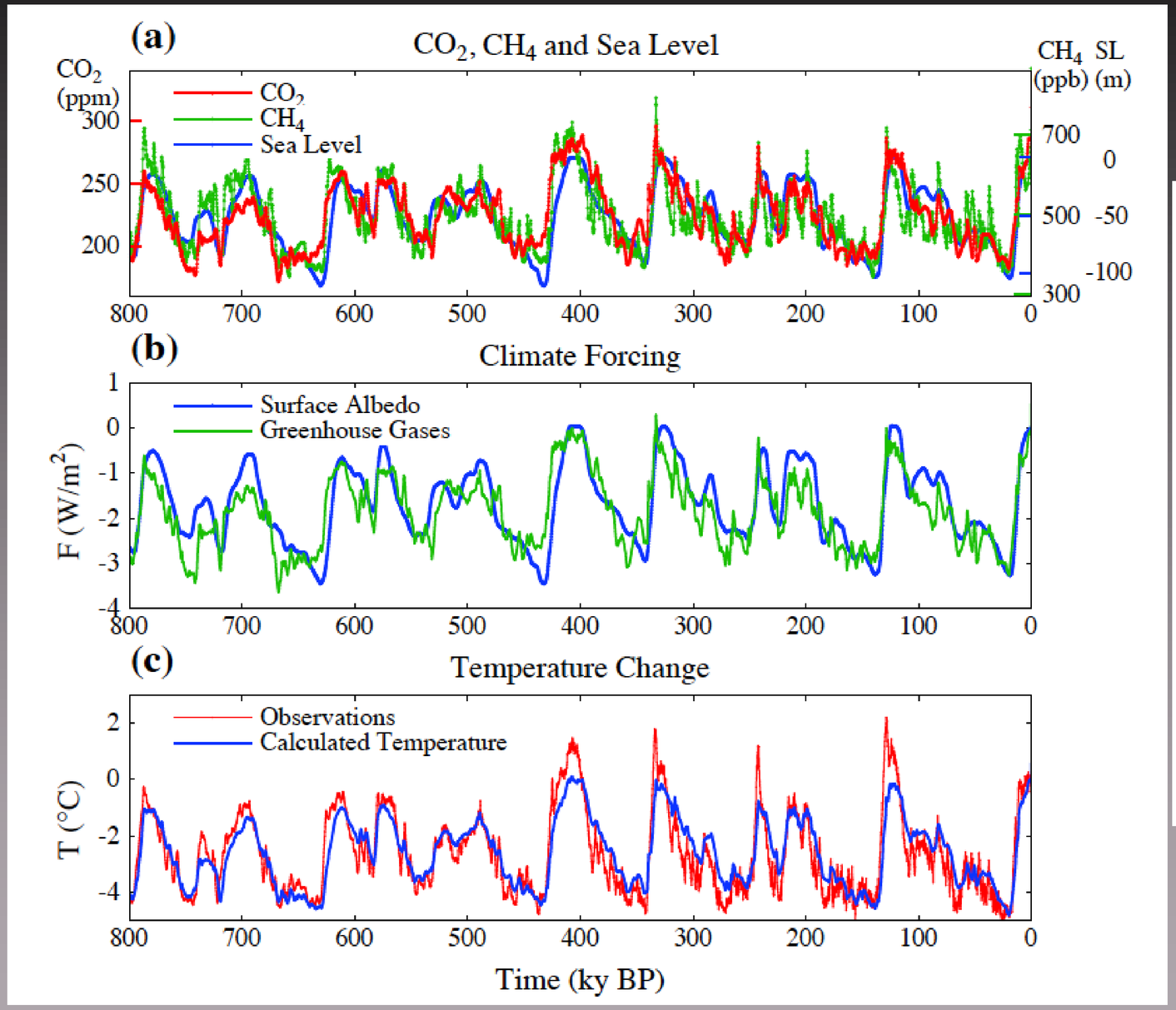
The Challenge of Climate Change and Sea Level Rise Adaptation

The Challenge of Climate Change and Sea Level Rise Adaptaion



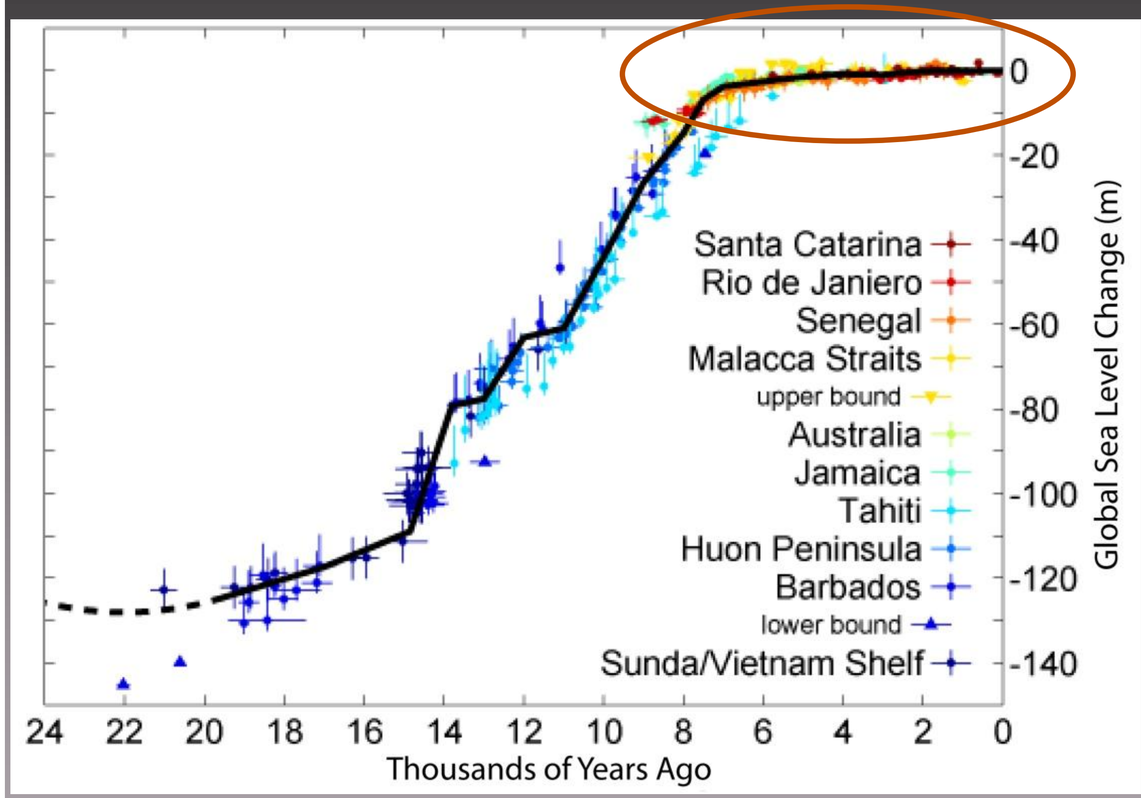
Modified from Church et al. (21010)

LONG-PERIOD SEA LEVEL CHANGES
- mean global and local sea level are not stationary in time



Hansen et al. (2008)

PDF



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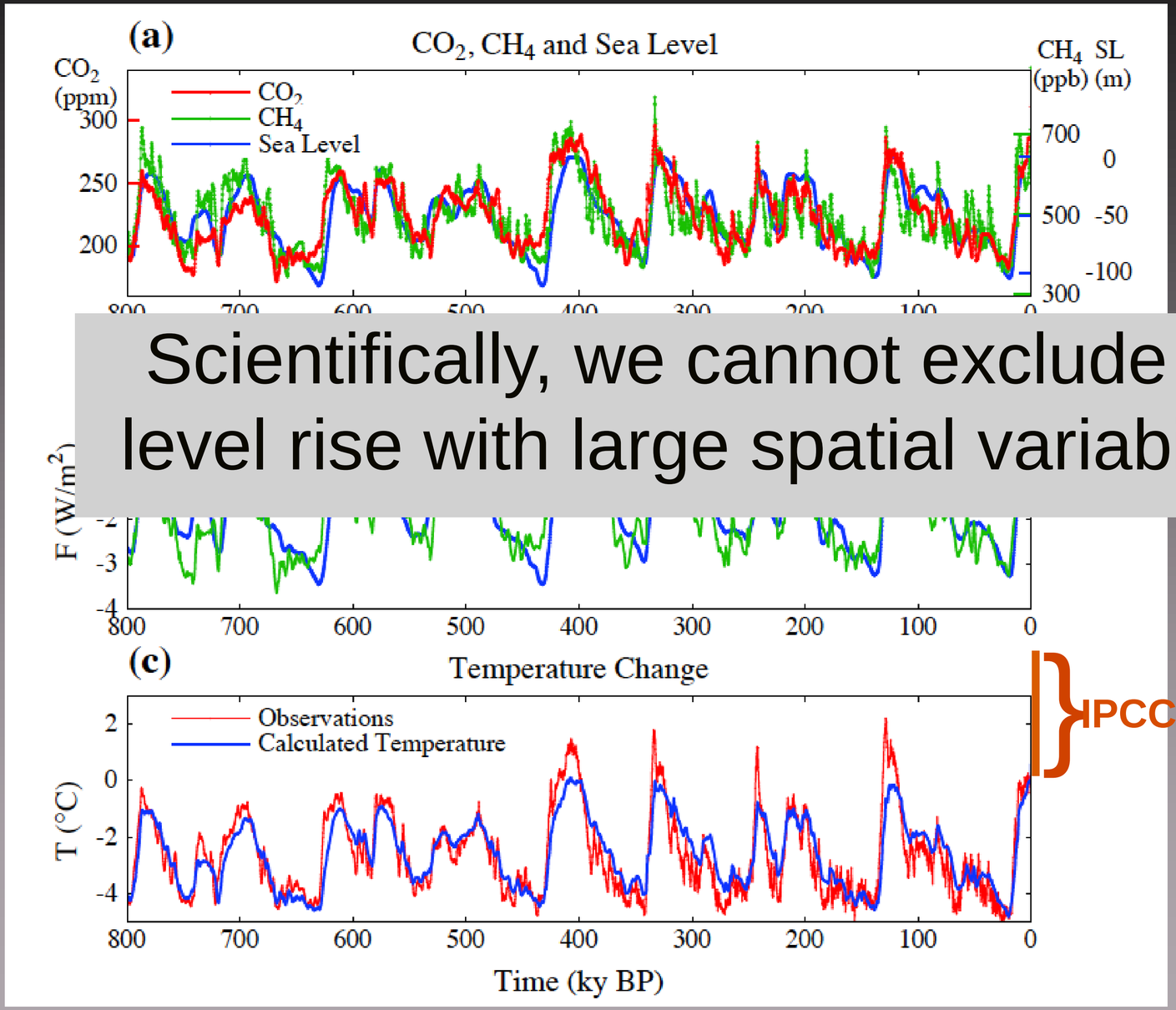

IPCC

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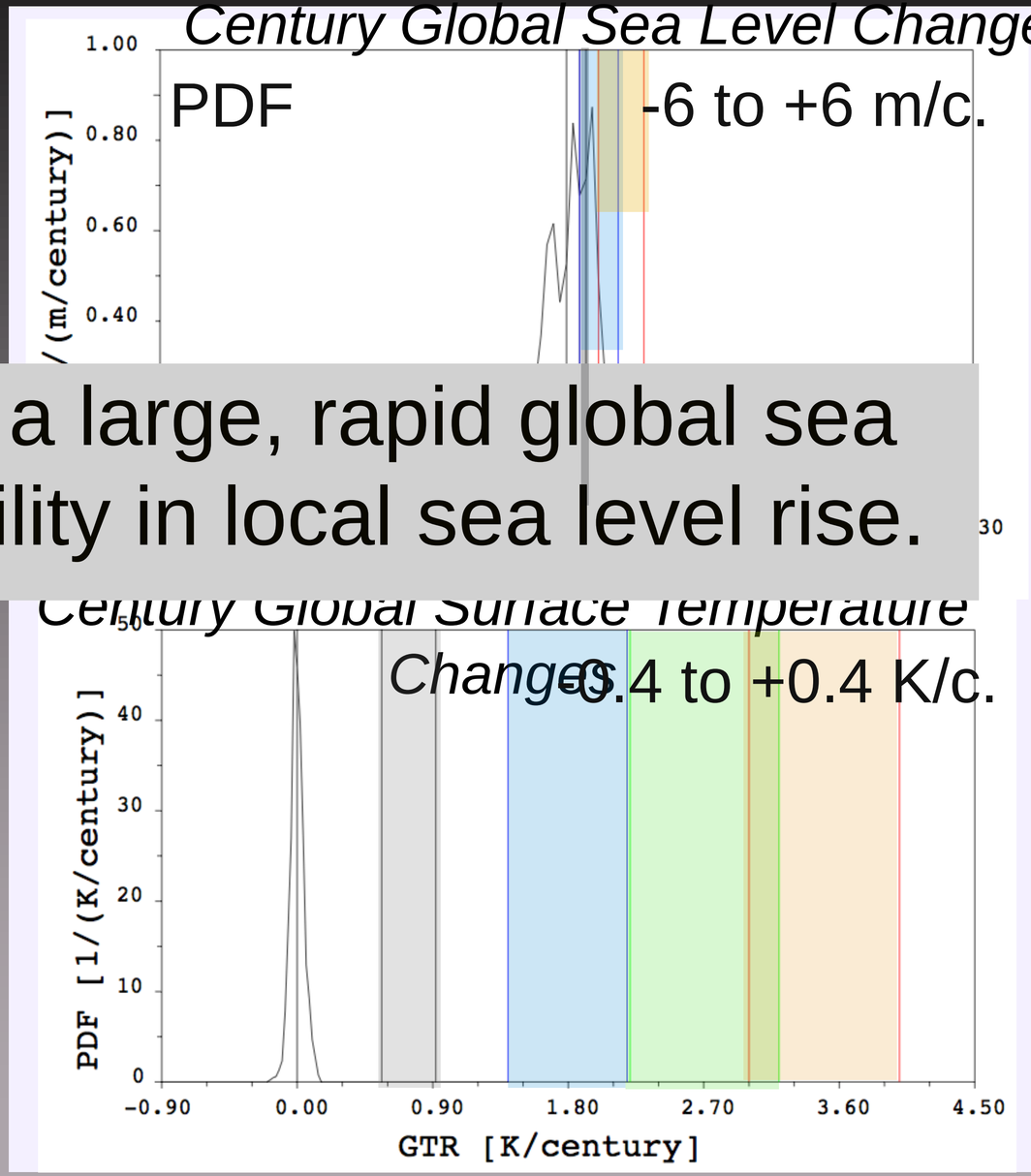
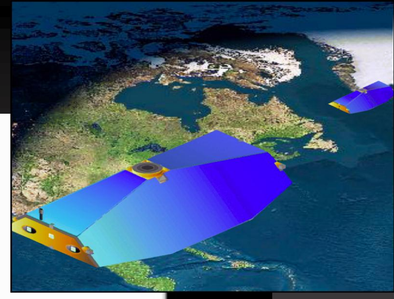
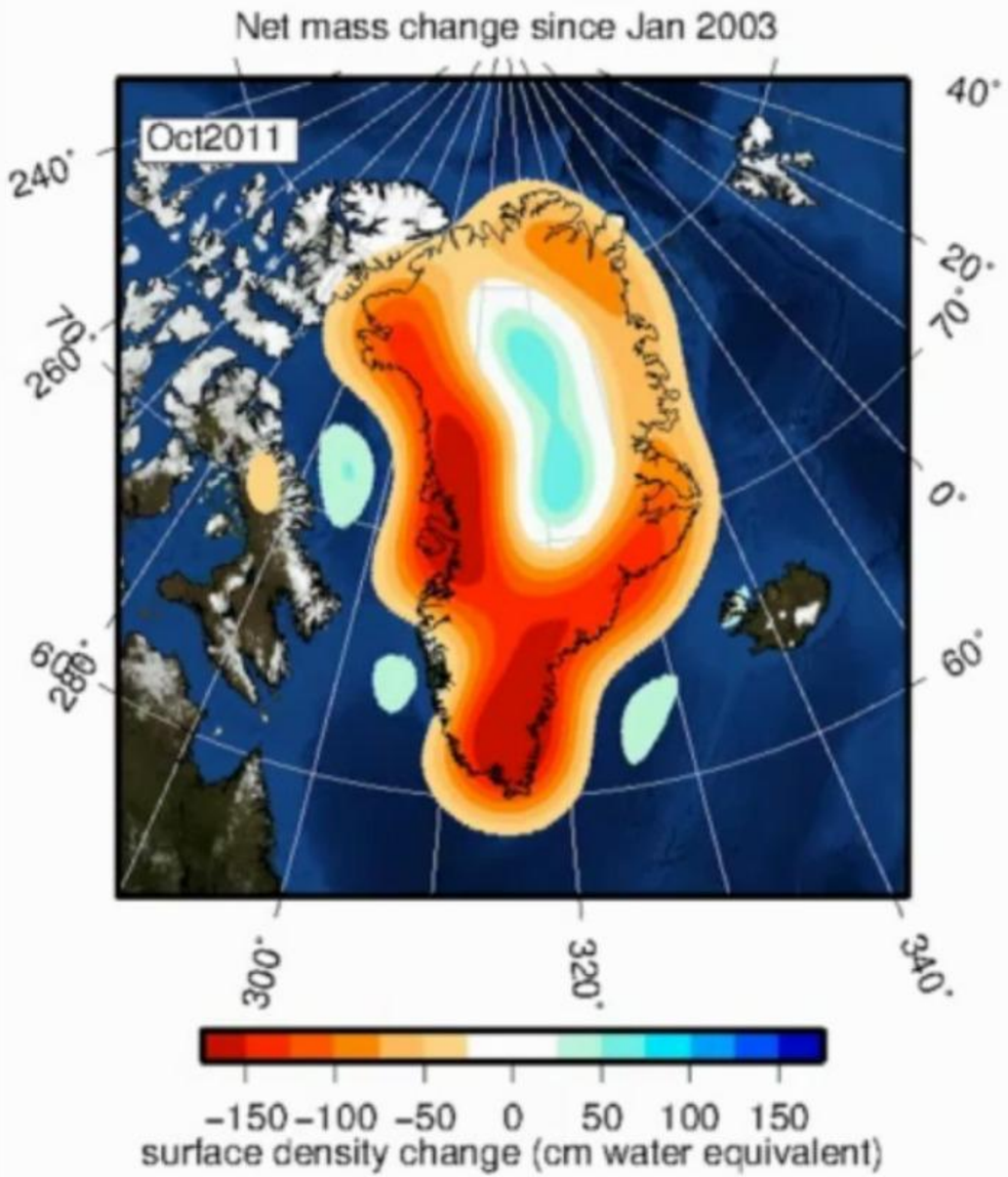


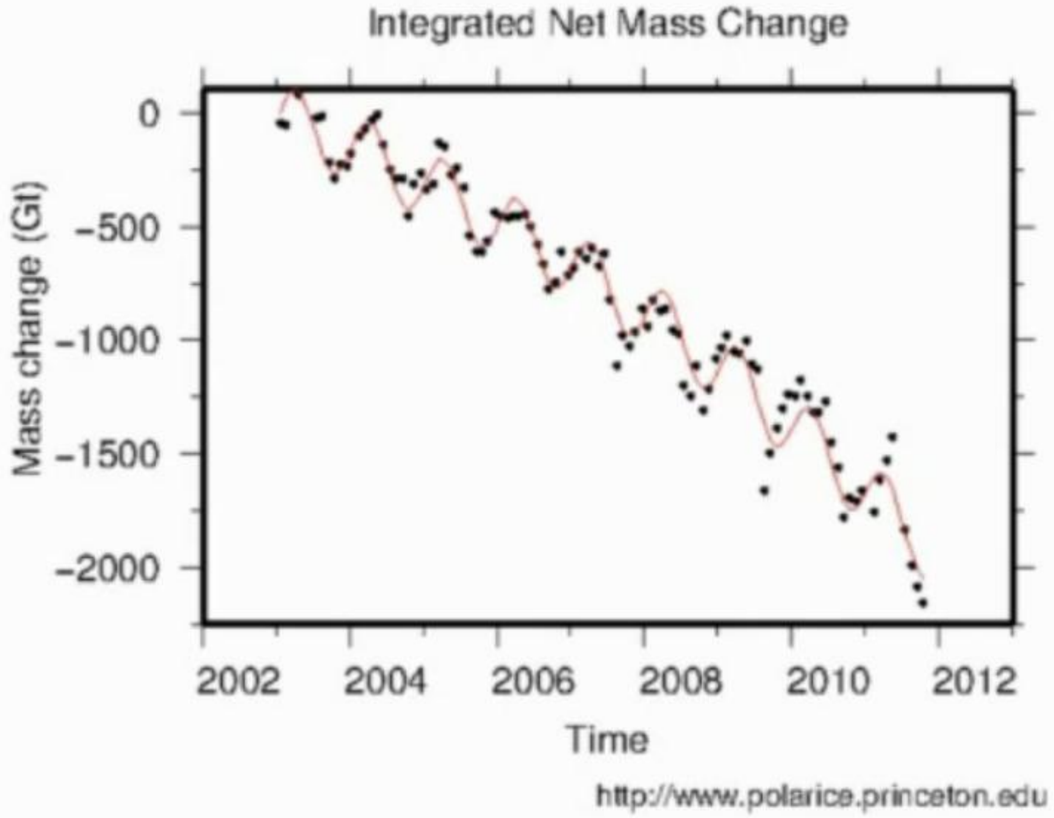
Plag and Jules-Plag (2013)

Scientifically, we cannot exclude a large, rapid global sea level rise with large spatial variability in local sea level rise.

Increased Melting of Ice Sheet(s)







http://www.polarice.princeton.edu

INCREASING IMPACTS

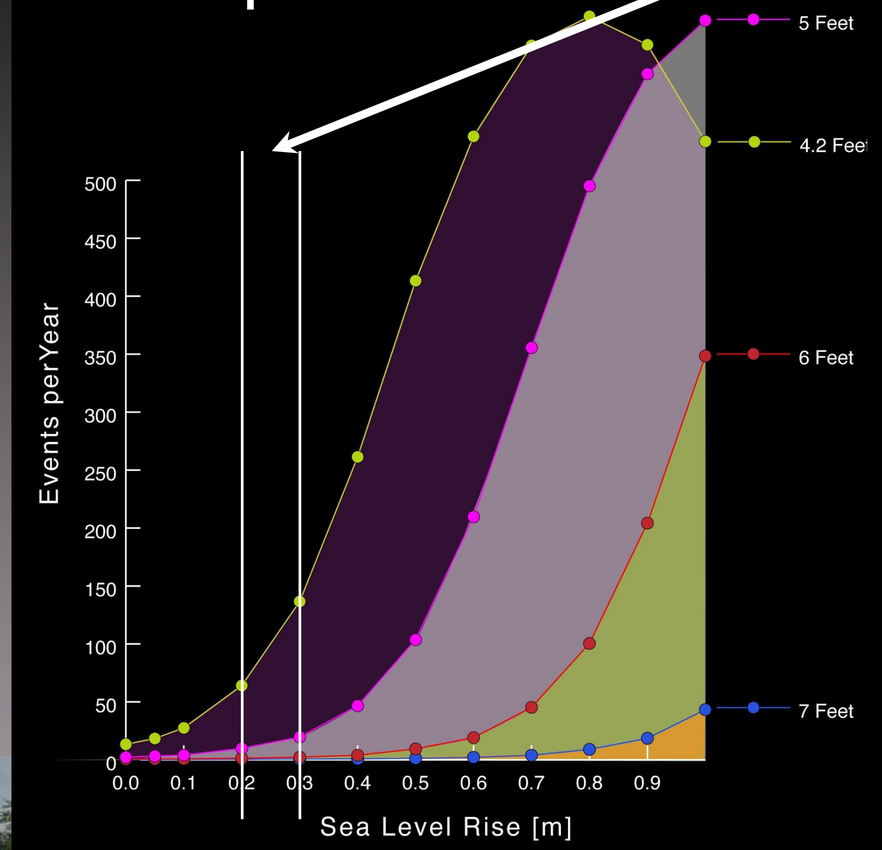
20 to 30 years

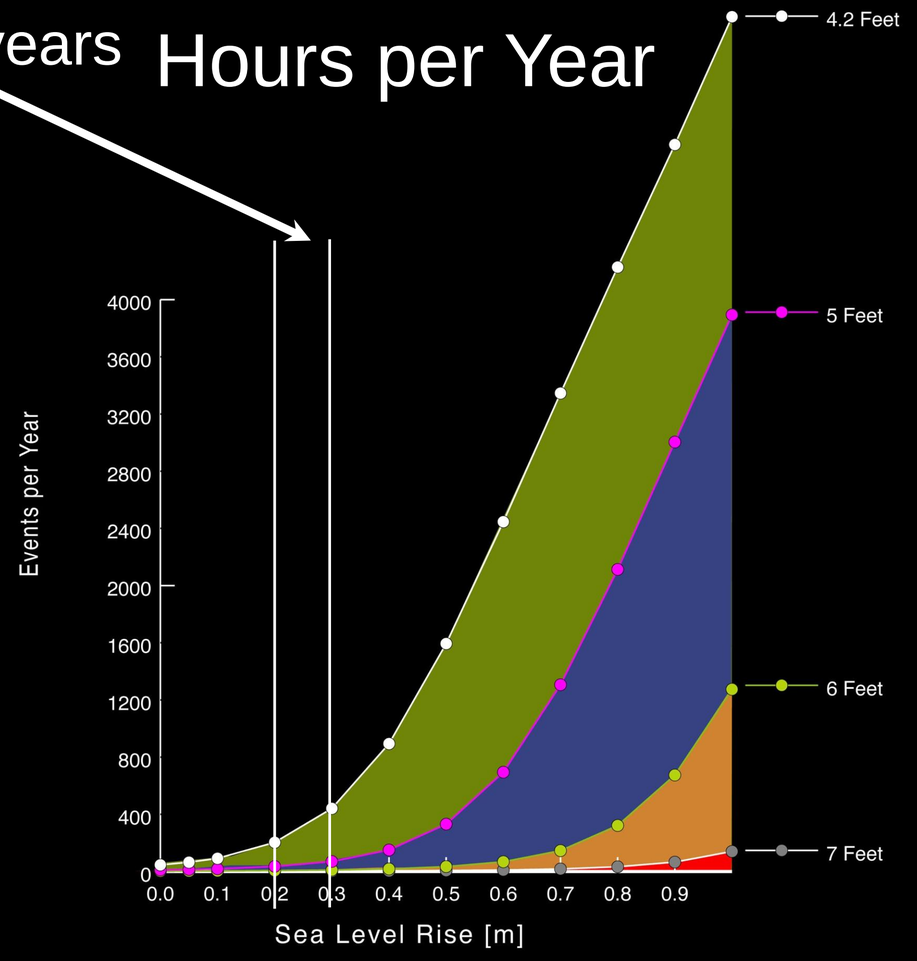
Events per Year

Hours per Year

Venice

Norfolk





Norfolk: Sea Level exceeding level that causes “nuisance flooding

Sea Level Rise is a slowly developing natural hazard that can lead to extreme disasters (X-events).

How are we handling other natural X-hazards?

Extreme natural hazards that could cause very high impacts:
- asteroids: early warning system in place, focusing on large objects; lead time a few years;
- droughts: working on a global monitoring service;
- pandemics: monitoring, high sensitivity;
- extreme geohazards; in particular, large volcano eruptions:
  no monitoring system in place, but InSAR could be a basis for a monitoring system;
  potentially very short lead times;

- rapid sea level rise: currently no prediction system;
  City managers: lead times required are on the order of 5 to 10 years.

We need “Early Warning Systems.”

A Interannual to Decadal Local Sea Level Forecasting Service is an Early Warning System

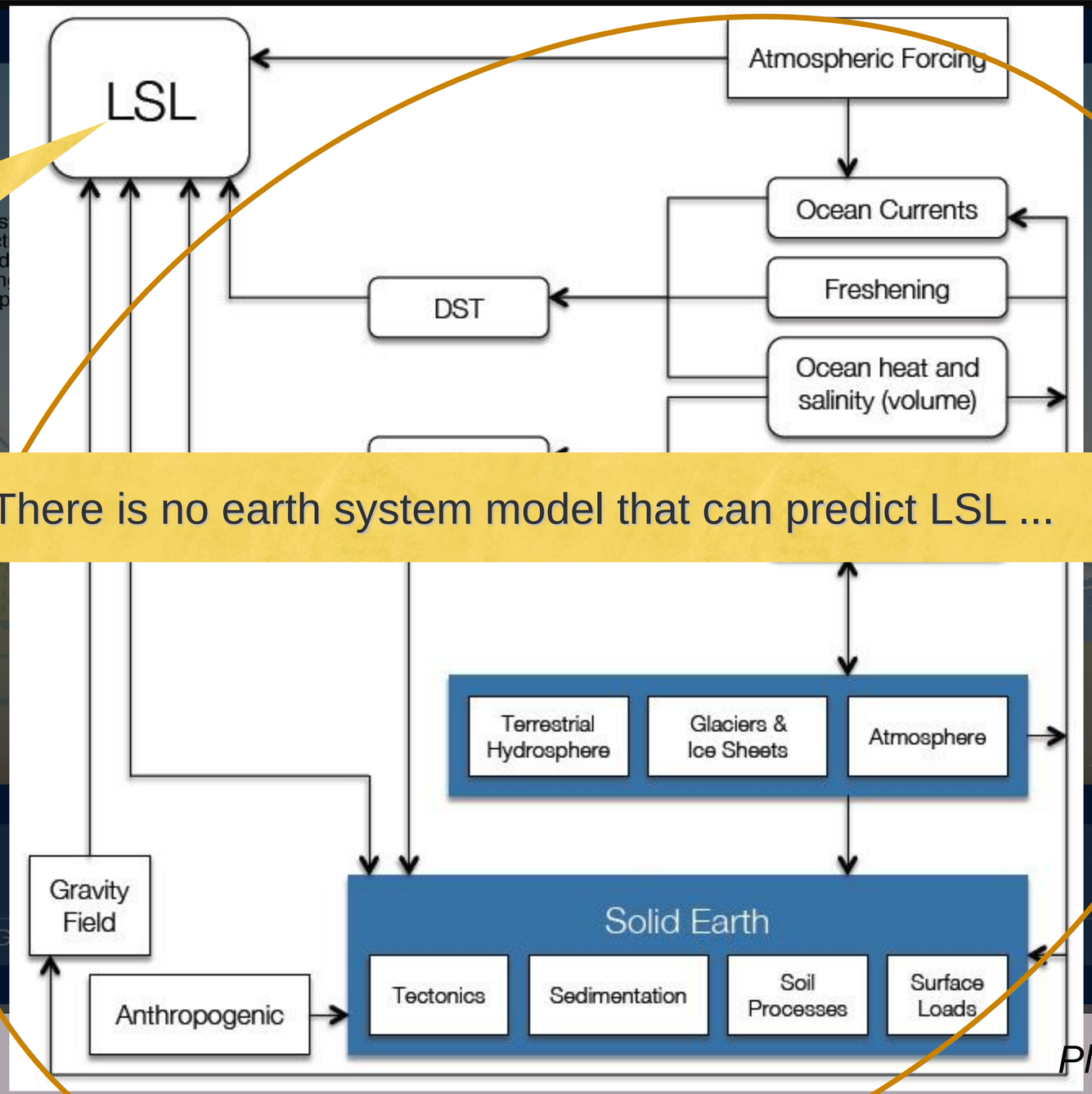
Plag et al., 2009

Can we do it?

Cumulative Equation of Local Sea Level Changes
A Modular System Model

Local Sea Level Changes

LSL is the output of Earth system processes



There is no earth system model that can predict LSL ...

Plag and Jules-Plag, 2013

Cumulative LSL Equation

LSL = short-period part + long-period part

Separation at a period of about 2 months:

High-frequency part of LSL equation:

$$h_{\mathrm{hf}}t = w(t) + h_{\mathrm{tidal}}(t) + h_{\mathrm{atmos}}(t) + h_{\mathrm{seiches}}(t) + h_{\mathrm{tsunami}}(t).$$

Important for projection of maximum flood levels

Short-period variations are the result of local to regional processes

Cumulative LSL Equation

LSL = short-period part + long-period part

Low-frequency part of LSL equation:

Contributing factors for LSL (monthly time scales and longer):

$$\delta h_{\mathrm{M}}(\vec{x},t) = S(\vec{x},t) + C(\vec{x},t) + A(\vec{x},t) + F(x,t) + I(\vec{x},t) + G(\vec{x},t) + T(\vec{x},t) + P(\vec{x})(t-t_0) + V_0(\vec{x})(t-t_0) + \delta V(\vec{x},t) + B(\vec{x},t)$$

Comments on the relation between mass changes (exchange and redistribution) and LSL:

All mass movements:

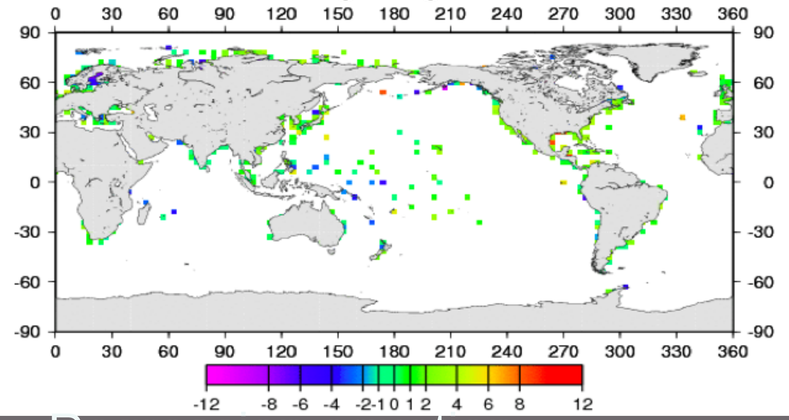
- change the geoid
- displace the ocean bottom vertically
- redistribute the water masses in the ocean

Important for projection of mean sea level

Long-period variations are the result of local to global processes

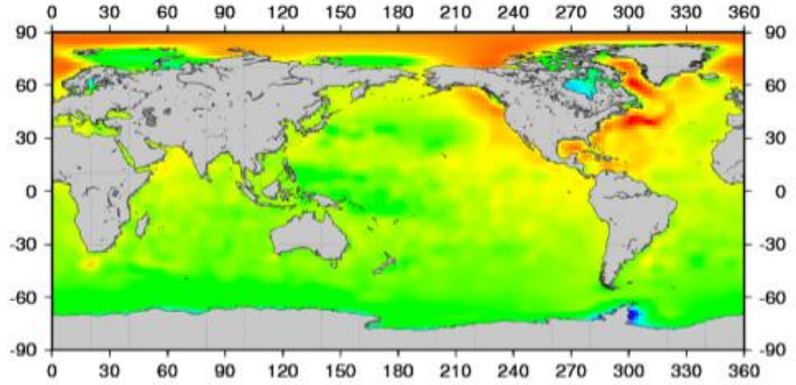
Reconstructing Global Sea Level From Tide Gauges (1950 - 2000)

tide gauges

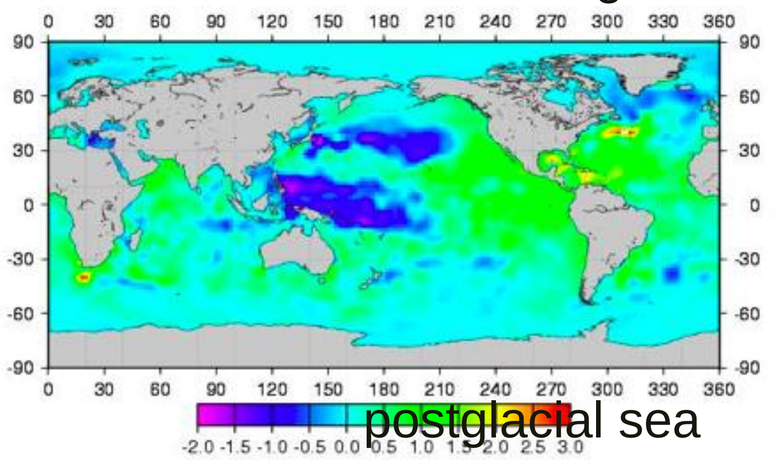


Regression equation included:
- steric changes
- post glacial rebound
- finger prints for Antarctic and Greenland Ice Sheets

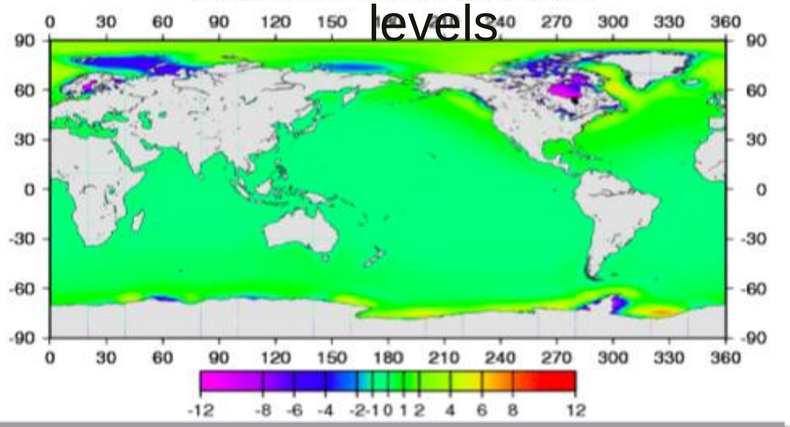
reconstructed LSL



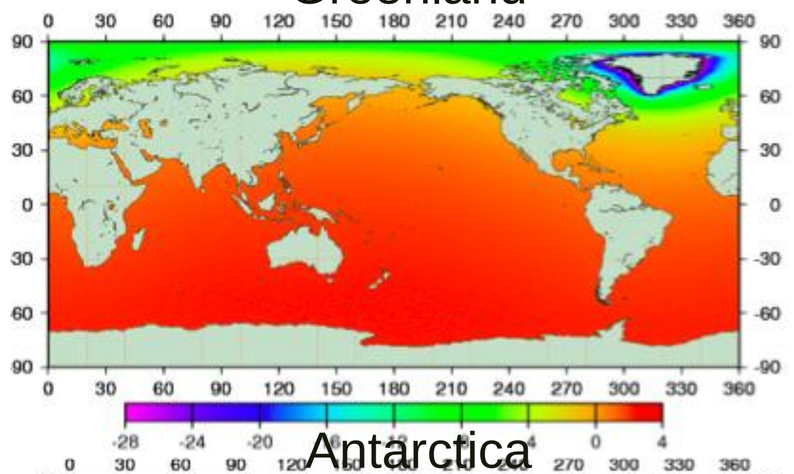
steric changes



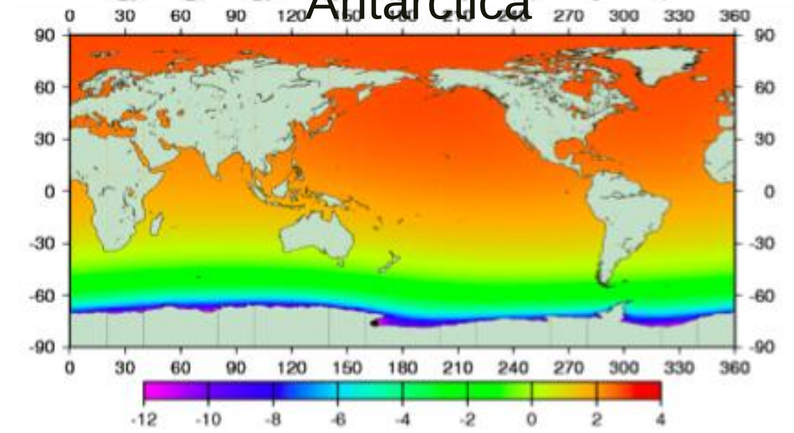
postglacial sea levels



Greenland



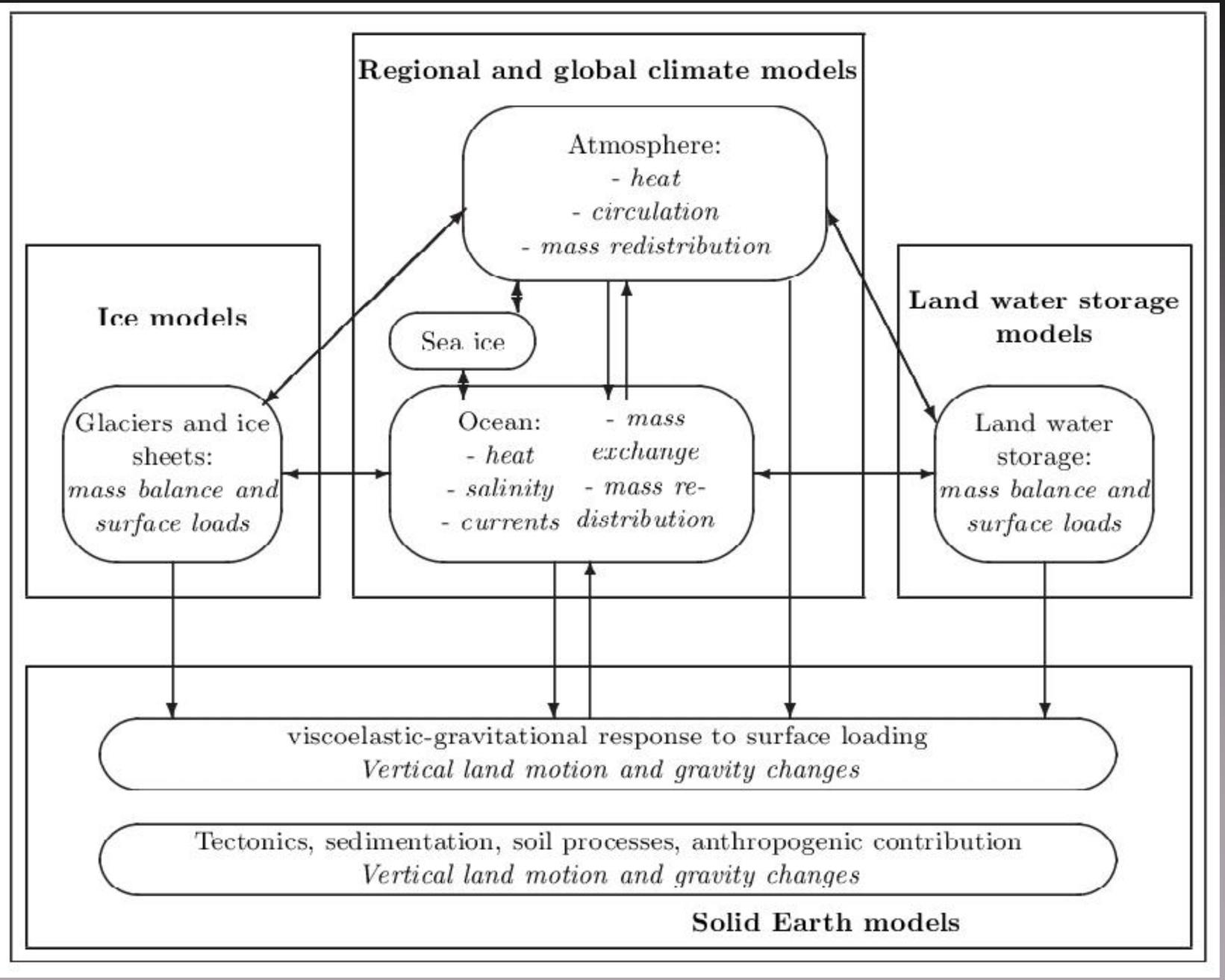
Antarctica



Example global average:
1.14 mm/yr at tide gauges
0.90 mm/yr global average

Plag, 2006

Hyprid Approach for Forecasting



Modular system model;
modules can be
- coupled models,
- empirical models, or
- observations

Observations provide constraints:

GRACE: mass
Satellite Altimetry: sea surface topograp
ARGOS: heat content, steric changes
Tide Gauges: LSL changes
GPS: vertical land motion
InSAR: vertical land motion

Current Status:

Overview of available modules
Next Steps

Overview of available modules

Postglacial rebound: mean model plus uncertainties (linear)
Present-day mass movement: geophysical (elastic) model plus observation/predictions of mass redistribution (land ice and land water storage)
mass redistribution:
- Land water storage: GLDAS + GRACE
- Ice sheets: GRACE, satellite altimetry, models
- Glaciers: extrapolation of observed trends

Vertical land motion: observations, extrapolation of recent trends
Atmospheric and ocean circulation: GCMs, regional models, and observations
Steric effects: ARGOS and other observations
Freshening: remote sensing and models

Constraints/assimilation:
- Global (water) mass balance
- Tide gauges and satellite altimetry
- Earth rotation observations

Next Steps

Global framework developed by us:
Will allow computation of LSL(x,t) for the next 10 years, including uncertainties
Use both deterministic and probabilistic approaches to forecasts

Community effort needed to improve modules (those based on models)
Tests with many different models for the different modules
Assessment of predictive capabilities

Part of the Work Plan of the Group on Earth Observations (GEO)
Supported by:
GEO Coastal Zone Community of Practice and
GEO Sea Level Rise Community of Practice

If you want to get involved, please contact me ...